Variable Target Model Filtering for Use with Angle Target Tracking Applications

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Abstract

A variable target model filter is investigated for use with angle target tracking applications. In the absence of a target maneuver, a "quiescent" target model is used for the tracking filter. In the presence of a target maneuver, the target model is shifted to a "maneuvering" model. The basis for using a "quiescent" target model in conjunction with a "maneuvering" target model is that accurate tracking performance can be obtained for both maneuvering and non-maneuvering situations as opposed to settling for an undesirable compromise. Simulation results indicate that the variable target model filter used for this work is capable of providing "best case" miss-distance/tracking performance for both maneuvering and non-maneuvering target conditions.

Introduction

A distinctive problem with many tracking filters is that their target models are quite often over-designed for either a (near) constant velocity target or a (near) constant acceleration target. As a result, degradation in performance is realized when a tracking filter containing an over-designed target model is applied to a class of targets it is not capable of handling. For instance, tracking filters strictly designed to handle non-maneuvering targets will suffer in the presence of a target maneuver because the necessary uncertainty (i.e., variance) required to model the higher-order motion of the target is not available. On the other hand, tracking filters strictly designed to handle maneuvering targets will suffer in the presence of no target maneuver because in attempting to model the (near) zero-acceleration component of the target motion, increased estimation errors for the lower-order states will result.

Consequently, in the work presented here, the target model of an angle target tracking filter is designed to nominally operate in a "quiescent" mode during the absence of a target maneuver. However, once a target maneuver has been detected, the target model is shifted to a "maneuvering" model. The premise for switching between a "quiescent" target model and a "maneuvering" target model is that accurate tracking performance can be obtained for both situations as opposed to settling for an undesirable compromise. Simulation results illustrate that the angle-frame variable target model tracking filter used for this work is capable of providing "best-case" miss-distance/tracking performance (i.e., "best-case" with respect to a target model optimized for a specific maneuver condition) for both maneuvering and non-maneuvering target conditions.

The breakdown of this work is outlined as follows: The standard target equations of motion (continuous-time and discrete-time) which will be referenced throughout this paper are provided in the opening section. Next, the discrete-time Kalman filter estimator equations used for modeling the standard target equations of motion are given. The "quiescent" target model, the "maneuvering" target model and the target detection scheme utilized for this work are then discussed in subsequent sections, and finally, simulation results conclude the paper.

Target Motion State Models

The standard, continuous-time target equation of motion is described as follows*:

$$\dot{x}(t) = F(t)x(t) + Gw(t) \tag{1}$$

* For simplicity, a single angle-frame tracking filter is referred to throughout this discussion. However, individual azimuth and elevation angle-frame tracking filters would most likely be desired for actual implementation.

Extending equation 1 to discrete-time yields the following:

$$x(k+1) = \Phi(k)x(k) + u(k) \tag{2}$$

where Φ is the target state transition matrix and u is an inhomogeneous driving input. It should be noted that even though the input u is not a sampled version of the continuous-time white noise input w of equation 1, it can be shown that u is white in the discrete time sense. Consequently, equation 2 is directly suitable for Kalman filter applications.[6] Furthermore, since

$$x(t+\Delta t) = e^{F\Delta t}x(t) + \int_t^{t+\Delta t} e^{F(t+\Delta t-\tau)}Gw(\tau)d\tau \tag{3}$$

it can be seen that for the discrete-time target state model provided in equation 2

$$\Phi(k) = e^{F\Delta t} \tag{4}$$

$$u(k) = \int_{k\Delta t}^{(k+1)\Delta t} e^{F[(k+1)\Delta t-\tau]}Gw(\tau)d\tau \tag{5}$$

Kalman Filter Equations

For this work, it is assumed that an active tracking sensor provides target position based upon the following angle measurement:

$$y(k) = Hx(k) + v(k) \tag{6}$$

where H is the observation matrix and v is additive white noise with variance R.

Equations 2 and 6 provide the necessary plant and observation models for the implementation of a discrete-time Kalman filter. The Kalman filter estimator equations used for this work utilize the following notation:[4]

1. Correction (based upon new measurement):

$$K_k = P_k(-)H_k^T[H_kP_k(-)H_k^T + R_k]^{-1} \tag{7}$$

$$\hat{x}_k(+) = \hat{x}_k(-) + K_k[\underline{y}_k - H_k\hat{x}_k(-)] \tag{8}$$

$$P_k(+) = [I - K_kH_k]P_k(-) \tag{9}$$

2. Propagation (to next measurement)

$$\hat{x}_{k+1}(-) = \Phi_k\hat{x}_k(+) \tag{10}$$

$$P_{k+1}(-) = \Phi_kP_k(+)\Phi_k^T + Q_k \tag{11}$$

where K is the optimal Kalman gain matrix, P is the state estimate error covariance matrix, y, H and R are taken from equation 6, Φ is taken from equation 4, and Q is the process noise covariance matrix based upon equation 5 and defined as follows:[6]

$$Q_k = E\{u_ku_k^T\} \tag{12}$$

Equations 7-12 provide the angle-frame target tracking state estimator equations used in this work for both the "quiescent" and "maneuvering" target models.

Quiescent Target Model

In the absence of a target maneuver, the target model is placed in a "quiescent" mode of operation. The "quiescent" target acceleration is modeled using a first-order markov process and process noise to allow for slight changes in the target's motion. The "quiescent" target model is defined by the following continuous-time parameters based upon equation 1:[3,6]

$$x = \begin{bmatrix} \lambda \\ \dot{\lambda} \\ N_T \end{bmatrix},\quad F = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1/r \\ 0 & 0 & -\alpha_q \end{bmatrix},\quad G = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

w_q = quiescent white noise driving function with power spectrum $\dfrac{2\sigma_{N_{Tq}}^2}{\tau_{N_{Tq}}}$

$\sigma_{N_{T_q}}$ = quiescent target acceleration standard deviation

$\tau_{N_{T_q}}$ = quiescent target acceleration time constant

α_q = inverse of quiescent target acceleration time constant

r = relative range measurement/estimate

Considering equations 4, 5, and 12, the "quiescent" target model parameters required for the implementation of a discrete-time Kalman filter are given as follows (assuming $\Delta t \ll \tau_{N_{T_q}}$):

$$\Phi(k) = e^{F\Delta t} = \begin{bmatrix} 1 & \Delta t & \Delta t^2/2r \\ 0 & 1 & \Delta t/r \\ 0 & 0 & e^{-\alpha_q \Delta t} \end{bmatrix}$$

$$u(k) = \int_{k\Delta t}^{(k+1)\Delta t} \begin{bmatrix} 1 & [(k+1)\Delta t - \tau] & [(k+1)\Delta t - \tau]^2/2r \\ 0 & 1 & [(k+1)\Delta t - \tau]/r \\ 0 & 0 & e^{-\alpha_q [(k+1)\Delta t - \tau]} \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} w(\tau) d\tau$$

$$Q(k) = \frac{2\sigma_{N_{Tq}}^2}{\tau_{N_{Tq}}} \begin{bmatrix} \Delta t^5/20r^2 & \Delta t^4/8r^2 & \Delta t^3/6r \\ \Delta t^4/8r^2 & \Delta t^3/3r^2 & \Delta t^2/2r \\ \Delta t^3/6r & \Delta t^2/2r & \Delta t \end{bmatrix}$$

$$H = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

Maneuvering Target Model

When a target maneuver has been detected, the target model is shifted to a "maneuvering" mode of operation. The "maneuvering" target acceleration is modeled using a first-order markov process and process noise to allow for severe changes in the target's motion. The "maneuvering" target model is defined by the following continuous-time parameters based upon equation 1:[3,6]

$$x = \begin{bmatrix} \lambda \\ \dot{\lambda} \\ N_T \end{bmatrix}, \quad F = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1/r \\ 0 & 0 & -\alpha_m \end{bmatrix}, \quad G = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

w_q = maneuver white noise driving function with power spectrum $\frac{2\sigma_{N_{Tm}}^2}{\tau_{N_{Tm}}}$

$\sigma_{N_{T_m}}$ = maneuver target acceleration standard deviation

$\tau_{N_{T_m}}$ = maneuver target acceleration time constant

α_m = inverse of maneuver target acceleration time constant

r = relative range measurement/estimate

Again, considering equations 4, 5, and 12, the "maneuvering" target model parameters required for the implementation of a discrete-time Kalman filter are given as follows (assuming $\Delta t \ll \tau_{N_{T_m}}$):

$$\Phi(k) = e^{F\Delta t} = \begin{bmatrix} 1 & \Delta t & \Delta t^2/2r \\ 0 & 1 & \Delta t/r \\ 0 & 0 & e^{-\alpha_m \Delta t} \end{bmatrix}$$

$$u(k) = \int_{k\Delta t}^{(k+1)\Delta t} \begin{bmatrix} 1 & [(k+1)\Delta t - \tau] & [(k+1)\Delta t - \tau]^2/2r \\ 0 & 1 & [(k+1)\Delta t - \tau]/r \\ 0 & 0 & e^{-\alpha_m [(k+1)\Delta t - \tau]} \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} w(\tau) d\tau$$

$$Q(k) = \frac{2\sigma_{N_{T_m}}^2}{\tau_{N_{T_m}}} \begin{bmatrix} \Delta t^5/20r^2 & \Delta t^4/8r^2 & \Delta t^3/6r \\ \Delta t^4/8r^2 & \Delta t^3/3r^2 & \Delta t^2/2r \\ \Delta t^3/6r & \Delta t^2/2r & \Delta t \end{bmatrix}$$

$$H = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

Target Maneuver Detection

The target maneuver detection scheme used for this work is based on a fading memory average of the "quiescent" target model's normalized innovations as follows:[1,2]

$$\mu(k) = \gamma_1 \mu(k-2) + \gamma_2 \mu(k-1) + \frac{[y(k) - \hat{x}_1(k)]^2}{P_{11}(k) + R(k)} \quad (13)$$

where: y = line-of-sight measurement

$\hat{x}_1$ = line-of-sight state estimate

P_{11} = line-of-sight state estimate error covariance

R = line-of-sight measurement noise variance estimate

$0 < \gamma_1, \gamma_2 < 1$

Basically, assuming a "quiescent" mode of operation, on the occasion that equation 13 exceeds a given threshold it is accepted that a target maneuver is present, and the "maneuvering" target model is transitioned to from the "quiescent" target model. The "quiescent" target model is then returned to if the estimated target accelerations over a certain "window" of time become statistically insignificant with respect to their standard deviations. The test statistic used to determine the significance of the target acceleration estimates while in a "maneuvering" mode of operation is given as follows:[1,2]

$$\rho(k) = \sum_{j=k-l+1}^{k} \delta(j) \tag{14}$$

where: $\delta(j) = \dfrac{\hat{N}_T(j)^2}{P_{33}(j)}$

$\hat{N}_T$ = target acceleration state estimate

P_{33} = target acceleration state estimate error covariance

l = window length

Consequently, for a specific window length, l, when the sum of equation 14 exceeds unity, the target acceleration is deemed significant with respect to its standard deviation and vice-versa. Furthermore, in order to allow for a smoother transition between the "quiescent" and "maneuvering" target models, once the "maneuvering" target model has been initiated, each time the resultant summation of equation 14 exceeds unity a maneuver probability value is incremented by 0.1. Similarly, each time the resultant summation of equation 14 is less than unity the same maneuver probability value is decremented by 0.1. Basically, this maneuver probability value represents the severity of the target maneuver and can be used to weight the "maneuvering" target model's process noise in order to provide a more seamless transition between target models. In addition, once the maneuver probability reaches zero the "quiescent" target model is reinstated.

The "maneuvering" target model's process noise weighted by the aforementioned maneuver probability is given as follows:

$$Q(k) = \frac{2\sigma_{N_{T_m}}^{\ 2}}{\tau_{N_{T_m}}} \begin{bmatrix} \Delta t^5/20r^2 & \Delta t^4/8r^2 & \Delta t^3/6r \\ \Delta t^4/8r^2 & \Delta t^3/3r^2 & \Delta t^2/2r \\ \Delta t^3/6r & \Delta t^2/2r & \Delta t \end{bmatrix} prob(k)$$

Simulation Results

In order to evaluate the performance of the angle-frame variable target model filter, various parameters (i.e., $\sigma_{N_T}^{\ 2}, \tau_{N_T}$) required for the "quiescent" and "maneuvering" modes of operation need to be determined.

Consequently, for the "quiescent" target model, if the normal target acceleration (N_T) is assumed to be a random variable uniformly distributed over the interval $(-N_{T_{max}}, N_{T_{max}})$, then its corresponding variance can be computed as follows:[5]

$$\sigma_{N_T}^{\ 2} = E\{X_{N_T}^{\ 2}\} = \frac{1}{2N_{T_{max}}} \int_{-N_{T_{max}}}^{N_{T_{max}}} x_{N_T}^{\ 2} dx = \frac{N_{T_{max}}^{\ 2}}{3} \tag{15}$$

During a "quiescent" mode of operation, any change in target motion is assumed to be solely attributed to atmospheric turbulence/wind effects. Consequently, the maximum expected "quiescent" lateral target acceleration used for this work is assumed to be 1 gee. As a result, the target acceleration variance required for computing the "quiescent" target model's process noise is given as follows:

$$\sigma_{N_{T_q}}^{\ 2} = \frac{(1.0 \cdot 9.807)^2}{3} = 32.059 \quad (\mathrm{m^2/sec^4})$$

For a "maneuvering" mode of operation, any change in target motion is believed to be the result of an intentional target maneuver. For this work, the maximum expected "maneuvering" lateral target acceleration is assumed to be 6 gees. Consequently, the target acceleration variance required for computing the "maneuvering" target model's process noise is given as follows:

$$\sigma_{N_{T_m}}^{\ 2} = \frac{(6.0 \cdot 9.807)^2}{3} = 1154.1270 \quad (\mathrm{m^2/sec^4})$$

The time constants used for this work (τ_{N_T}) refer to the *duration* of the expected "target maneuver". For a "quiescent" mode of operation, typical time constants corresponding to atmospheric turbulence/wind effects have been shown to be on the order of 1-2 seconds.[6] Consequently, for this work a time constant of 2 seconds (i.e., α_q = 0.5) is used to model the atmospheric turbulence/wind effects for the "quiescent" target model. Similarly, for a "maneuvering" mode of operation, typical target maneuver time constants for the application under consideration can range anywhere from 1-10 seconds. As a result, for this work a time constant of 4 seconds (i.e., α_m = 0.25) is used to model the intentional target maneuver effects for the "maneuvering" target model.

The simulation results presented in the following figures compare Monte Carlo performance data obtained for a constant "quiescent" target model, a constant "maneuvering" target model, and a variable target model corresponding to two different target maneuver scenarios. The two target maneuver scenarios considered for this work are described as follows:

1. No target maneuver.
2. Evasive elevation maneuver (6gee pullup) induced at a time-to-go of 3 seconds.

In addition to the above, the following target initial conditions and parameters further describe the simulation scenarios investigated for this work:

1. Target initial downrange of 25km.
2. Target initial altitude of 100m.
3. Target velocity of 150 m/s.
4. Target flying straight in along primary target line (PTL).

Figure #1 illustrates the miss-distance performance of the various target models corresponding to target maneuver scenario #1. From this figure it can be seen that all three target models essentially provide similar miss-distance performance.

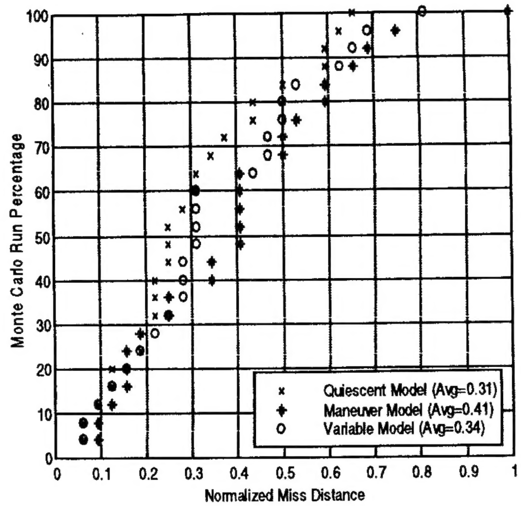

Figure #1 Normalized Miss-Distance Performance For Target Maneuver Scenario #1

Table I provides the tracking performance of the various target models corresponding to target maneuver scenario #1. The performance index, J, used for this work is described as follows:

$$J_i = \frac{\sum_{k=1}^{N} \left| x_i(k) - \hat{x}_i(k) \right|}{N} \tag{16}$$

where: x_i = i^{th} true state

$\hat{x}_i$ = i^{th} state estimate

N = number of data samples

i = state number (i = 1,2,3)

In addition to the individual tracking performance indices of each state and each filter, Table I also provides an overall tracking performance index which is calculated as the sum of the individual azimuth and elevation tracking performance indices corresponding to each of the three states within the tracking filter.

Table I Tracking Performance For
Target Maneuver Scenario #1

	Constant-Quiescent Model	Constant-Maneuver Model	Variable Model
LOS			
Azimuth	3.4218e-5	4.7793e-5	3.7204e-5
Elevation	1.3610e-4	1.3869e-4	1.3822e-4
LOS Rate			
Azimuth	1.4895e-4	2.5301e-4	1.3937e-4
Elevation	2.6890e-4	2.7739e-4	2.4813e-4
Acceleration			
Azimuth	0.0910	0.7410	0.0976
Elevation	0.0652	0.4016	0.0961
Overall Performance (Sum of J_i's)	0.1568	1.1433	0.1943

From Table I it can be seen that the tracking performance of the "constant-maneuver" target model suffers in the absence of a target maneuver while the "constant-quiescent" target model and the "variable" target model track the non-maneuvering target quite well.

Finally, Figure #2 illustrates the line-of-sight rate tracking performance of the various target models corresponding to target maneuver scenario #1. From this figure it can be seen that the line-of-sight rate estimates provided by the "constant-maneuver" target model are fairly "noisy" while those provided by the "constant-quiescent" target model and the "variable" target model are quite clean. The reason for the "noise" observed on the "constant-maneuver" target model's line-of-sight rate estimates is that while attempting tc [illegible] the (near) zero acceleration component of the target motion, the high-level of target maneuver uncertainty inherent within the "constant-maneuver" target model induces increased estimation errors for the lower-order states.

Figure #3 displays the miss-distance performance of the various target models corresponding to target maneuver scenario #2. From this figure it can be seen that the "constant-quiescent" target model significantly suffers in the presence of a target maneuver while the "constant-maneuver" target model and the "variable" target model perform quite well.

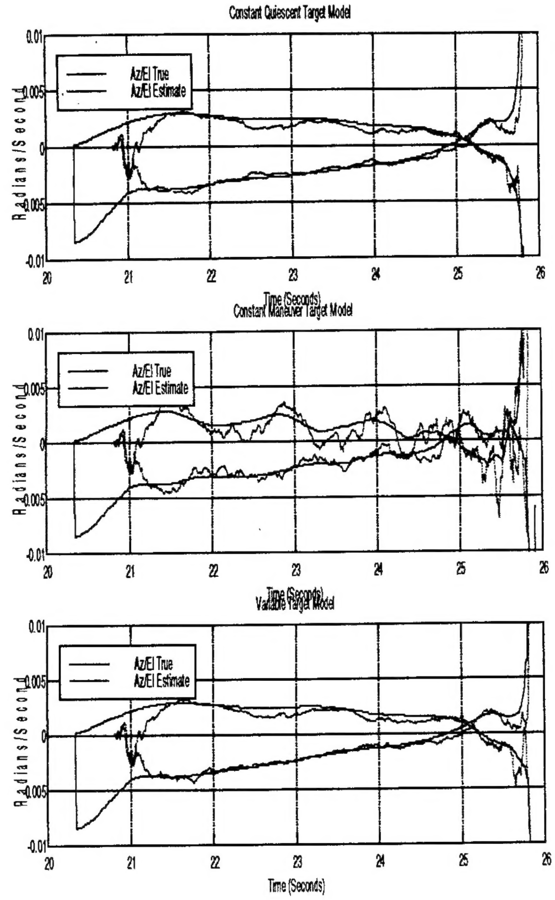

Figure #2 LOS Rate Tracking Performance
For Target Maneuver Scenario #1

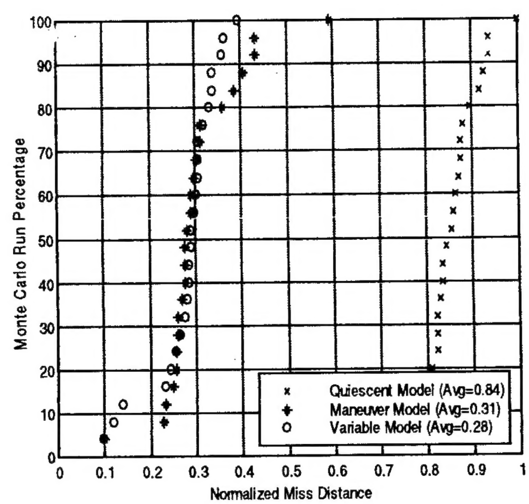

Figure #3 Normalized Miss-Distance Performance
For Target Maneuver Scenario #2

Table II provides the tracking performance of the various target models corresponding to target maneuver scenario #2.

Table II Tracking Performance For Target Maneuver Scenario #2

	Constant-Quiescent Model	Constant-Maneuver Model	Variable Model
LOS			
Azimuth	5.5317e-5	4.9445e-5	4.5561e-5
Elevation	1.4245e-4	1.3285e-4	1.3008e-4
LOS Rate			
Azimuth	2.5661e-4	2.3578e-4	2.0963e-4
Elevation	9.7831e-4	3.8342e-4	3.7928e-4
Acceleration			
Azimuth	0.1242	0.6918	0.1410
Elevation	1.1370	0.7810	0.6826
Overall Performance (Sum of J_i's)	1.2626	1.4736	0.8244

From Table II it appears that the "constant-quiescent" target model tracks the maneuvering target better than the "constant-maneuver" target model. However, a closer look reveals an explanation for the seemingly misleading results. Basically, prior to the end-game maneuver, the "constant-quiescent" target model provides the better tracking performance in both channels (i.e., azimuth and elevation) while during the target maneuver, the "constant-maneuver" target model provides the better tracking performance i the maneuver channel only. Consequently, when considering both channels throughout the duration of the flight, the tracking performance of the "constant-quiescent" and "constant-maneuver" target models becomes "compromised" which leads to similar "overall" tracking performance indices. On the other hand, it can be seen from Table II that the "variable" target model is capable of providing "best-case" tracking performance for both non-maneuvering and maneuvering target conditions. For instance, prior to the end-game maneuver, the "variable" target model is capable of providing tracking performance comparable to the "constant-quiescent" target model while during the target maneuver, the "variable" target model is capable of providing tracking performance comparable to the "constant-maneuver" target model in the maneuver channel and the "constant-quiescent" target model in the non-maneuver channel.

Finally, Figure #4 displays the line-of-sight rate tracking performance of the various target models corresponding to target maneuver scenario #2. From this figure it is observed that, again, the "constant-quiescent" target model provides the better tracking performance prior to the end-game maneuver while the "constant-maneuver" target model provides the better tracking performance during the maneuver (in the maneuver channel only). Furthermore, it can also be seen that the "variable" target model is capable of providing "best-case" tracking performance (in both channels) prior to and during the end-game maneuver.

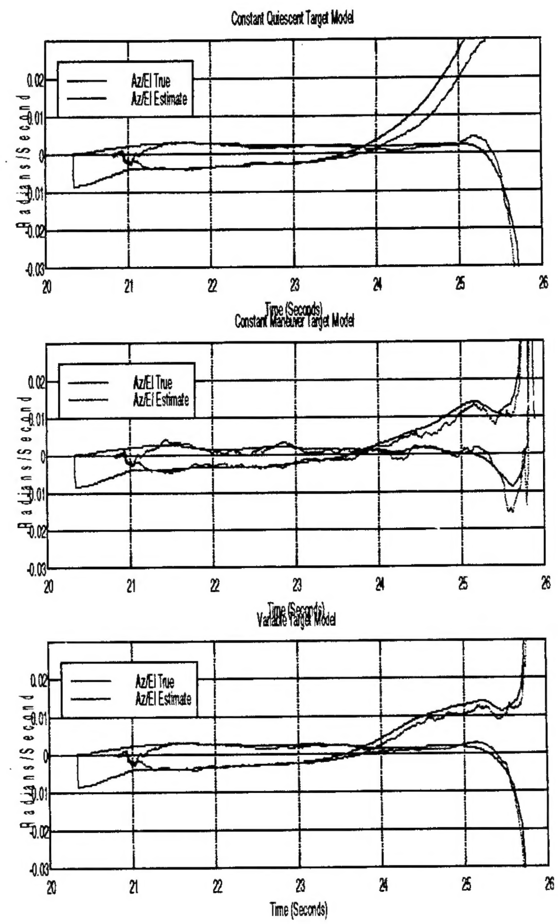

Figure #4 LOS Rate Tracking Performance For Target Maneuver Scenario #2

Conclusion

A variable target model filter has been investigated for use with angle target tracking applications. The filter's target model is shifted between a "quiescent" mode of operation and a "maneuvering" mode of operation based upon the absence or presence of a target maneuver. The basis for using a "quiescent" target model in conjunction with a "maneuvering" target model is that accurate tracking performance can be obtained for both maneuvering and non-maneuvering situations as opposed to settling for an undesirable compromise. Simulation results illustrate that the variable target model filter is capable of providing "best-case" miss-distance/tracking performance (i.e., "best-case" with respect to a target model optimized for a specific maneuver condition) for both maneuvering and non-maneuvering target conditions.

References

1. Bar-Shalom, Y., Birmiwal, K., "Variable Dimension Filter for Maneuvering Target Tracking", IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-18, No. 5, pp. 621-629, September 1982.

2. Bar-Shalom, Y., Fortmann, T.E., *Tracking and Data Association*, Academic Press, N.Y., 1988.

3. Blackman, S.S., *Multiple-Target Tracking With Radar Applications*, Artech House, MA., 1986.

4. Gelb, A., *Applied Optimal Estimation*, MIT Press, MA., 1974.

5. Papoulis, A., *Probability, Random Variables, and Stochastic Processes*, McGraw Hill, N.Y., 1984.

6. Singer, R.A., "Estimating Optimal Tracking Filter Performance for Manned Maneuvering Targets", IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-6, No. 4, pp.473-483, July 1970.

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